Long term variability of Cen X−3 with MAXI

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Abstract

Cen X−3 is an O-type donor Supergiant X-ray Binary with a neutron star as a compact object. The aim of this work is to study both the light curve and orbital phase spectroscopy of this system in the long term. Here we estimate the **orbital period from the light curve** and then we derive the good time interval to extract the spectrum from different orbital phases. We obtain **orbital phase-averaged** and **phase-resolved spectra** and we analyse the variability of the model parameters to infer properties of the circumstellar environment of Cen X-3 and possible dependences of the spectral parameters. The MAXI spectra in the 2-20 keV energy range were fitted with **a model of Comptonisation of cool photons on hot electrons modified by a partial covering absorption and a fluorescence iron emission line at 6.4 keV**.

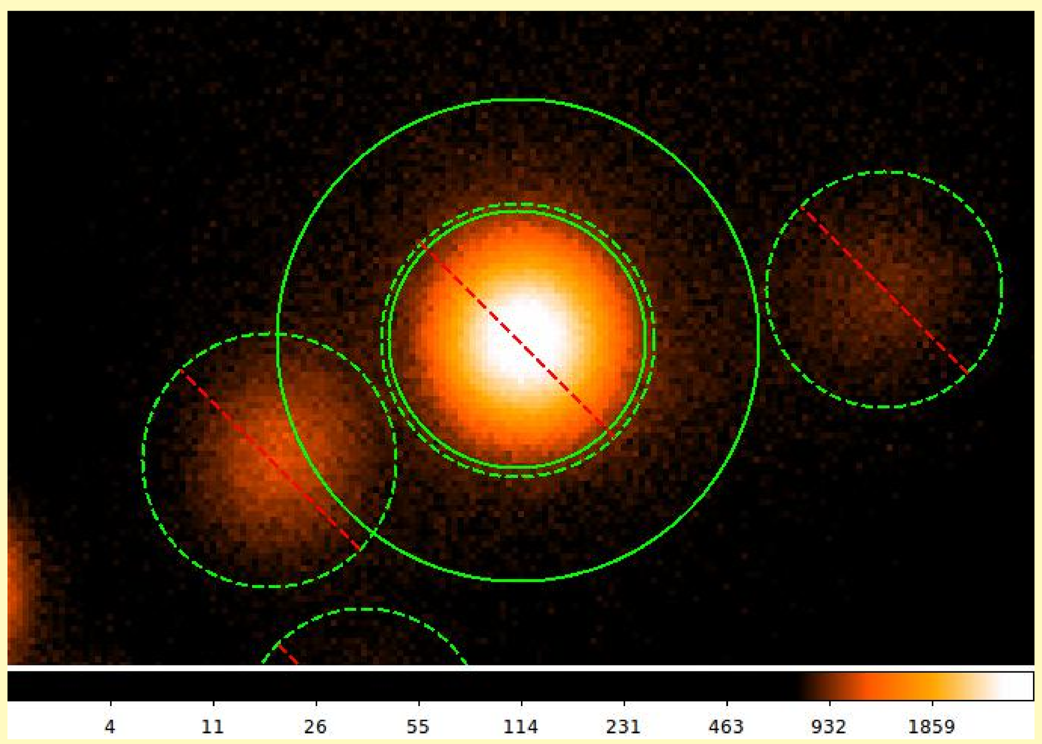
Introduction

The eclipsing high mass X-ray binary (HMXB) pulsar Cen X-3 has an O-type supergiant companion, V779 Cen. The orbital period of the binary system is ~2.1 days with a low eccentricity of ≤0.0016 [1] and the magnetised neutron star has a spin period of ~4.8 s [7]. The distance to the source was estimated to be ~8 kpc [4], although [9] gave a value of 5.7± 1.5 kpc.

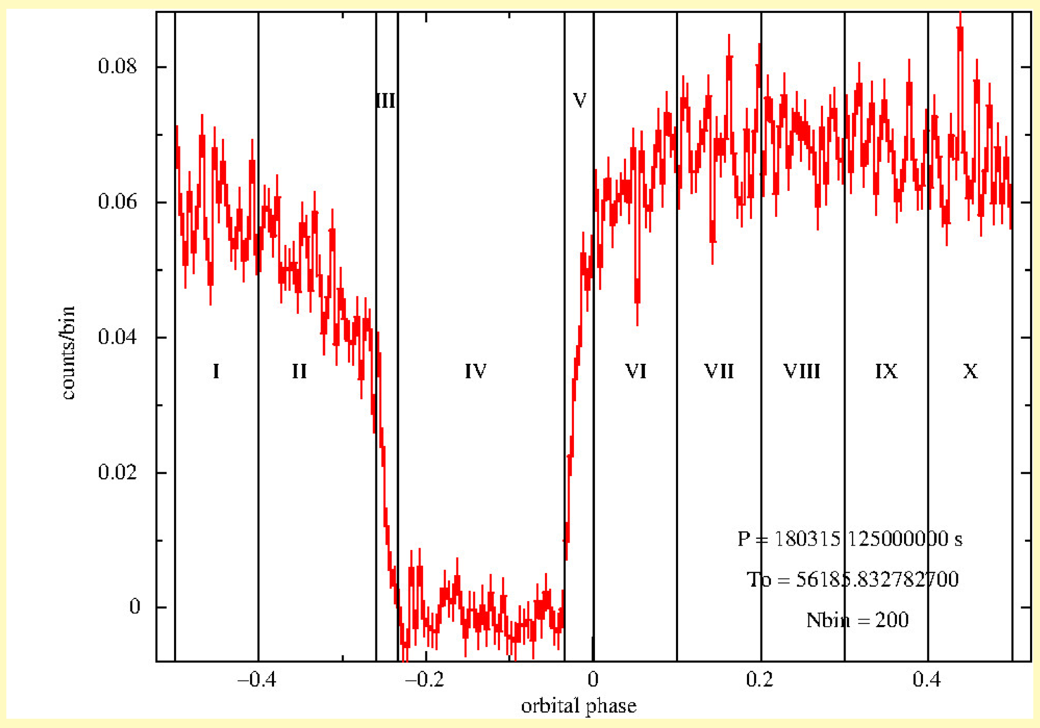
The **Monitor of All Sky X-ray Image** (*MAXI*) presents both all-sky coverage and moderate energy resolution, which gives us the possibility to investigate the orbital light curves and the orbital phased-resolved spectra of **Cen X−3** [6]. *MAXI* observing strategy suppress effectively the short term variability associated with accretion and enhances the long term, permanent structures present in the stellar wind and circumsource environment [2], [3].

Timing analysis

First, we have obtained the *MAXI/GSC* on-demand light-curve of Cen X−3 from MJD 55 058 to MJD 57 315 (i.e. more than 6 years) in the 2–20 keV energy band. Then, we have searched for a **period** assuming a sinusoidal signal and derived a $P_{\rm orb} = 2.0870 \pm 0.0006$ **days** which is consistent with the value given by [5].



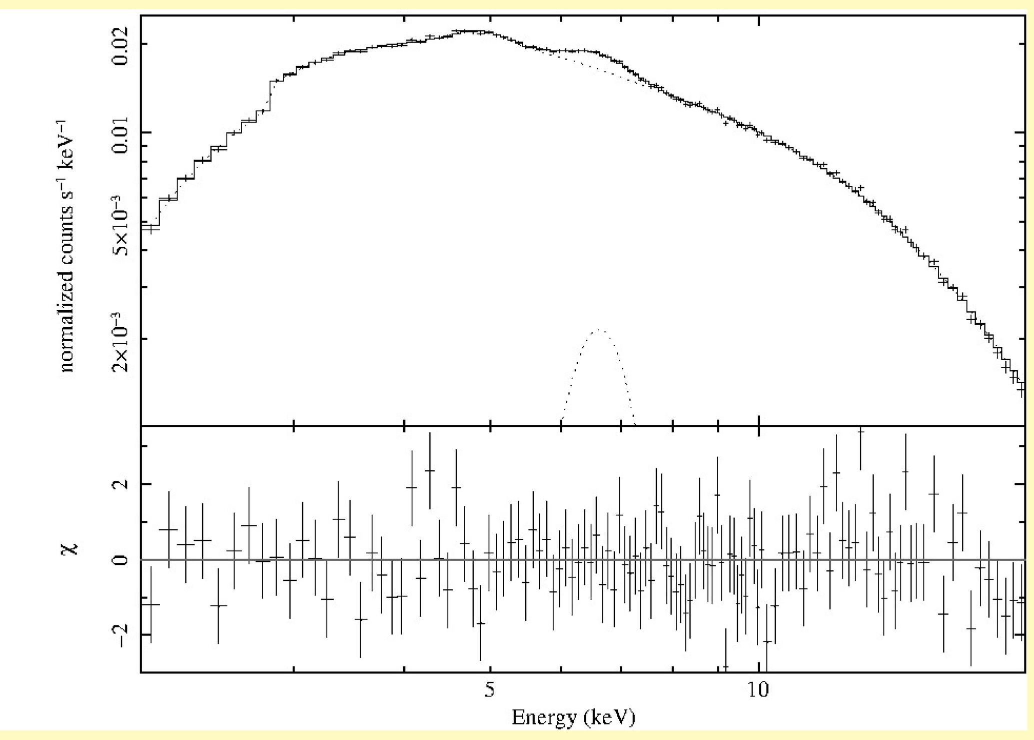
a) The extraction region



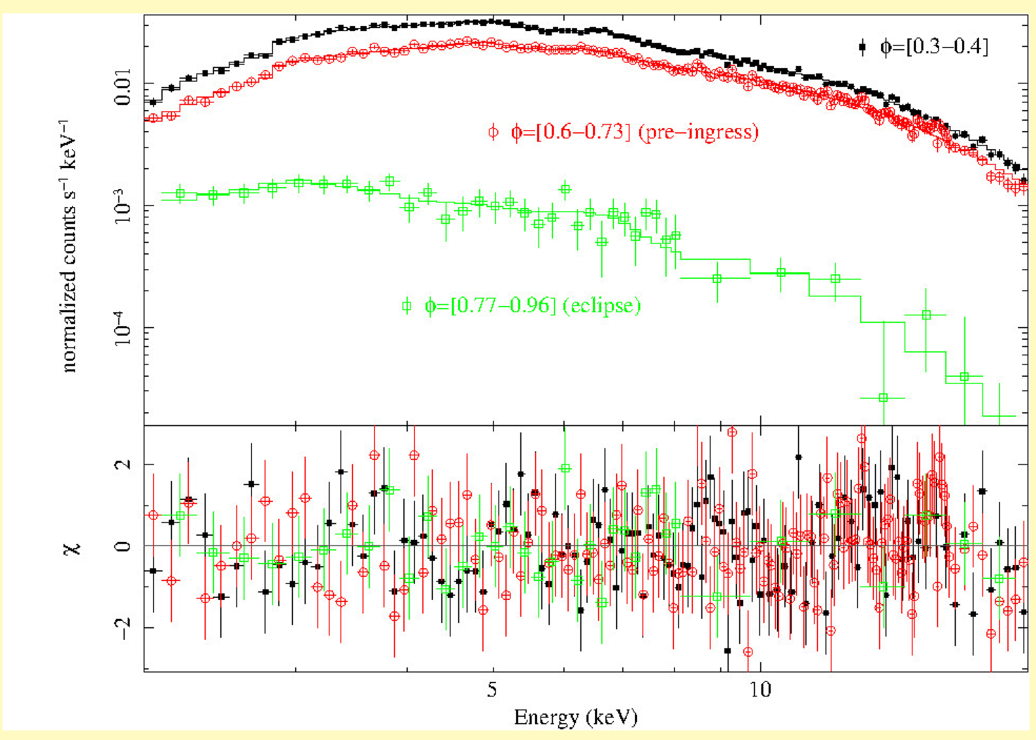
b) Background subtracted light curves

Spectral analysis

We have extracted the orbital phase-averaged spectrum of Cen X−3 with *MAXI/GSC* using the *MAXI* on-demand processing, carefully excluding any contamination by nearby brighter sources. We tested both phenomenological and physical models commonly applied to accreting X-ray pulsars. We rebined all extracted spectra to obtain spectral bins Gaussian distributed. The best fit was attained using COMPST, in XSPEC terminology [8], modified by a partial covering model implementation of the Tübingen-Boulder absorption model (*TBnew*) which includes the most up to date absorption cross sections and abundances [10]. We needed to put an additional Gaussian absorption line at ~5 keV to compensate the incompleteness of the *GSC* response (Nakahira private communication). Moreover, the fluorescence iron emission line at ~6.4 keV was also present in the spectrum.



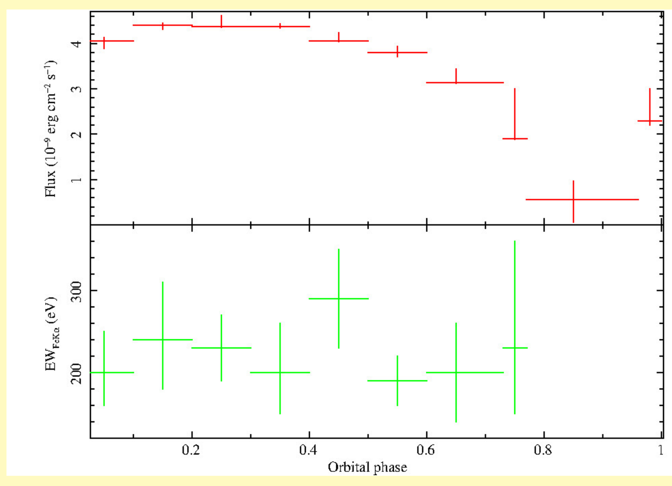
a) Averaged spectrum



b) Phase-resolved spectra

Then we have obtained **orbital phase-resolved spectra** of the HMXB pulsar Cen X−3 accumulating the 60 s duration scans into 10 orbital phase bins. We have fitted the orbital phase-resolved spectra with the same model we used in the orbital phase averaged spectrum. Nevertheless, no absorption Gaussian component at 5 keV was needed in these fits. We note that the optical counterpart blocked most of the X-ray emission in eclipse in all the energy bands, so there is no scattering in the wind. For the **fluorescence iron emission line**, a Gaussian profile is assumed. Moreover, this iron line is **not detected** both in the **eclipse and egress spectra** nor resolved the complex iron line in the energy range 6.4–6.7 keV.

Orbital phase-resolved spectra



The **unabsorbed flux** appears nearly constant in the orbital phase range $[0.1 - 0.4]$, $F_{(2-20)\,\rm keV} \sim 4.4 \times 10^{9}\,\rm erg\,cm^{-2}\,s^{-1}$, showing that **the accretion rate is quite stable**. The relative flux during the eclipse is a factor of 4 smaller than during out of eclipse.

The **equivalent width** (EW) of the Fe Kα is consistent with a constant value of $\sim 220 \pm 60$ **eV** taking into account the uncertainties. The centre of the energy of the iron line changes with orbital phase suggesting the **coexistence of two iron lines at different energies**.

References

[1] Bildsten, L. et al. 1997 *ApJS, 113, 367*
[2] Doroshenko, V. et al. 2013 *A&A, 554, A37*
[3] Islam, N. & Paul B. 2014 *MNRAS, 441, 2539*
[4] Krzeminski, W. 1974 *ApJ, 192, L135*
[5] Nagase, F., Corbet, R. H. D. et al. 1992 *ApJ, 396, 147*
[6] Rodes-Roca, J. J., Mihara, T. et al. 2016 *A&A, to be submitted*
[7] Schreier, E., Levinson, R. et al. 1972 *ApJ, 172, L79*
[8] Sunyaev, R. A. & Titarchuk, L. G. 1980 *A&A, 86, 121*
[9] Thompson, T. W. J. & Rothschild, R. E. 2009 *ApJ, 691, 1744*
[10] Wilms, J., Allen, A. & McCray, R. 2000 *ApJ, 542, 914*

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